A short study of some aspects of the ecology of rodent fleas in castle Eden Dene.

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A Short Study of Some Aspects of the Ecology of Rodent Fleas in Castle Eden Dene.

A Dissertation

Presented for the Degree of M.Sc.

by

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Abbreviations.

The following abbreviations have been used for scientific names of species:

Full scientific name.	Abbreviation.
Apodemus sylvaticus (Linnaeus)	*Apodemus*
Clethrionomys glareolus (Schreber)	*Clethrionomys*
Sorex araneus (Linnaeus)	*Sorex*
Talpa europaea (Linnaeus)	*Talpa*
Microtus agrestis (Linnaeus)	*Microtus*
Ctenophthalmus nobilis vulgaris (Smit)	*C.n.vulgaris*
Malaraeus penicilliger mustelae (Dale)	*Mal.p.mustelae*
Megabothris turbidus (Rothschild)	*Mega.turbidus*
Hystrichopsylla talpae talpae (Curtis)	*H.t.talpae*
Rhadinopsylla pentacantha (Rothschild)	*R.pentacantha*
Peromyscopsylla silvatica spectabilis (Rothschild)	*P.s.spectabilis*
Paleopsylla soricis soricis (Dale)	*Pal.s.soricis*
Doratopsylla dasycnema dasycnema (Rothschild)	*D.d.dasycnema*

SECTION 1

Introduction.

Until recently the ecology of fleas has been a much neglected topic,in contrast to the numerous studies made in relation to their epidemiological importance. Many general collections of bird and mammal fleas were made,by Dale(1878,1890),Rothschild (1895 - 1916),Thompson (1934 - 1955) and others. However,these were made without reference to the ecology of the fleas or hosts or the characteristics of the habitats in which they lived.

The earliest studies on the population ecology of fleas were carried out in connection with the classic plague investigations,in the early part of the twentieth century. These studies,which determined that rat fleas were responsible for the spread of plague,have been widely quoted in biological literature,and have set the style for many of the subsequent flea studies. Investigations were later carried out on the significance of the flea species associated with wild or campestral rodents involved in the sylvatic plague complex,the role of rat fleas as vectors of murine typhus,and the role of the European rabbit flea,Spilopsyllus cuniculi,in the spread of myxomatosis. Since these studies were of medical rather than ecological interest,the results and their presentation were orientated away from general ecology in many cases.

Elton et al (1931) made a study of the parasites and diseases of small mammals to determine the importance of infective diseases and of disease carriers as a cause of fluctuations in the populations of these animals,fleas being one of the groups of ectoparasites collected. This and succeeding studies under Elton's direction,produced no evidence that the spread of

epidemic disease was an important factor in the causation of the four-year population cycle in Microtus.

One of the first significant studies of fleas on an ecological basis was published by Evans and Freeman in 1950, though the work had been done in 1938 and 1939. The work was carried out in Bagley wood, near Oxford, and consisted of a study of the changes in the numbers of hosts and fleas, the flea populations of the individual hosts at each capture, and the rapidity with which the hosts acquired fleas.

In June 1964, Ashby, Bolton and Crawley (unpublished, and Ashby and Crawley, 1967) carried out a survey over a period of two weeks of the fleas of small mammals in Castle Eden Dene, using a line transect of two Longworth traps at 25-yard intervals over a distance of 1,650 metres and a grid of 200 x 150 metres with a grid interval of 20 metres. They obtained data on the flea species present, their hosts and mean densities, and the variations in the degree of infestation with species, sex, size and locality of host.

In 1968 another pilot study was made of the same area by O'Brien and Tilbrook (unpublished) to check the earlier results and also to investigate the rate and extent of reinfestation of rodents by fleas and the loss of fleas from rodents to bedding in Longworth traps.

One of the difficulties of basing estimates of flea populations on collections made on the rodent host is that the trapping or sampling of the host and its fleas may itself create a whole new range of variables. Removal of fleas from the area, by disinfestation of the hosts, may considerably lower the total flea population

available to the rodents if the reservoir available for reinfestation is low at the start. Secondly,trapping and disinfestation of the rodents,although it does not lower the rodent population of the area,may alter behaviour, especially in the case of lactating females which may thus be separated from their young for periods of up to 24 hours if the traps are only visited once daily,as was the case in this study.

There are strong indications that the population of fleas in the nests of the rodents is in certain circumstances very much greater than that carried by the hosts at any given time but to date no strict correlation has been shown to exist between the infestation level on the host and that in the nest. Stewart and Evans (1941) found that the flea population at the mouths of burrows of the ground squirrel,Citellus beecheyi,reflected with a high degree of accuracy,but on a smaller magnitude, the population density and species composition on the host. Cotton (1965),although studying the flea populations in the rodent nests,did not correlate these with the infestation on the bodies of the hosts.

The fieldwork for the present study was carried out from May to July 1970,in the same section of Castle Eden Dene as that used by Ashby,Crawley and Bolton (unpublished) and O'Brien and Tilbrook(unpublished). The aim of the work was to make a study of the fleas of small mammals in the Dene,with particular reference to

1. Reinfestation rates
2. Variations in infestation during the course of the summer and
3. The checking,as far as possible,of the conclusions

from the previous short-term studies in the Dene, in the light of the related studies by Evans and Freeman (1950) and others.

SECTION 2

The Study Area.

Castle Eden Dene,a local nature reserve,drains towards the sea from the East Durham plateau,which consists of Magnesium limestone covered by a thick layer of boulder clay. The Dene itself forms a narrow,steep-sided valley,bordered to the north by arable land and to the south by a golf course. A stream,polluted to some degree by coal washing,coking effluents and current road-works,runs through the Dene to the sea. This must form at least a slight barrier to the passage of small mammals from one side of the Dene to the other. The sheltered conditions and,in its lower reaches,the limestone outcrops of the Dene are associated with a rich flora and fauna,the former mainly natural or semi-natural woodland.

The western end of the Dene was marked out by Ashby,Bolton and Crawley in 1962 on a 50 metre square grid,based on the 100 metre co-ordinates of the national grid and the positions midway between them. Within the marked out area,three sites were chosen for the present study:one for the main bulk of the work and another two for additional experiments. Of these three,sites 1 and 2 corresponded approximately with grids A and B used by Crawley (unpublished) for his work on the small mammals of the Dene. The third was close to the western edge of the area,near to the roadworks for the new route of the A19 (see map 1). The three sites were marked out to accomodate 50 traps at 16 metre intervals on a square grid (5 rows of 10) on sites 1 and 2,and 25 traps at 16 metre intervals (5 rows of 5) on site 3.

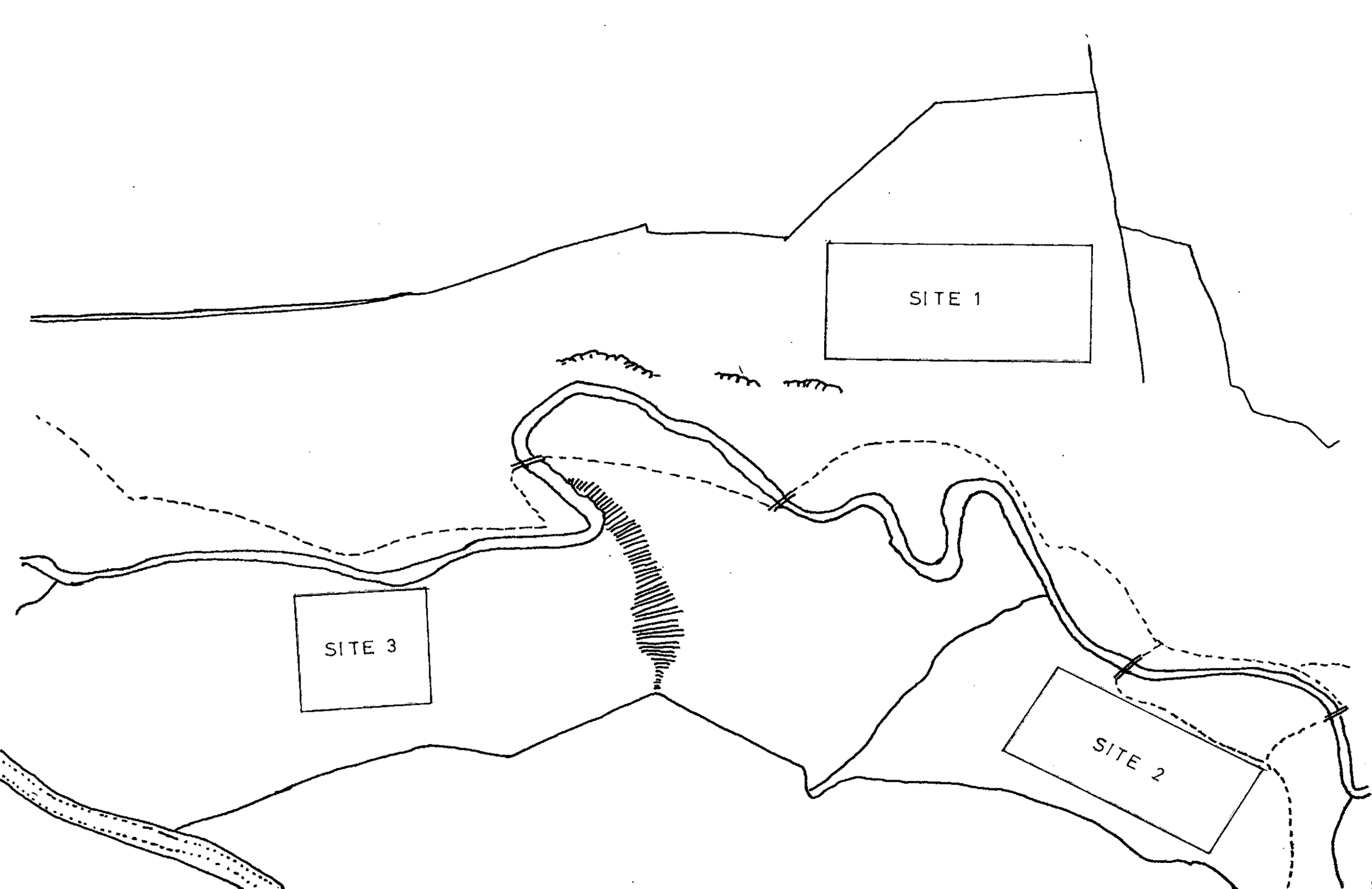
Sites 1 and 2 were sites of mixed tree cover.

CASTLE EDEN DENE, CO-DURHAM.

MAP 1

The trapping grids used.

SCALE : 18.5mm - 50metres


SITE 1
SITE 3
SITE 2

Site 1 lay partly in mature larch wood and partly in sycamore,with a narrow band of spruce,very wet and underlain with very little vegetation,separating them. Under the larch there was little ground cover except for a thick layer of larch-needle litter interspersed with small patches of bramble (Rubus rubus var.),bracken (Pteridium aquilinum),dogs mercury (Mercurialis perennis), and grass. Under the spruce the water table was at ground level in places and the vegetation consisted almost solely of grass and horsetails (Equisetum sp.),with areas of churned up mud in between due to trampling. The sycamore woodland had a moderately dense ground vegetation of grass,bramble,bracken,dogs mercury,rosebay willow-herb (Chamaenerium angustifolium) and red campion (Melandrium rubrum),affording some degree of cover throughout the whole year. The arrangement of the grid-lines was such that two lines of five traps lay in the larch,one line of five lay in the wet spruce area,and the rest lay in sycamore. Towards the east end of the grid the ground became steeper,traps I1,J1 and J2 lying on quite a steep and fairly bare slope.

On site 2 the majority of the trap lines were in larch woodland on a moderate slope,while two lines were laid in an adjoining ash plantation,the lower traps of these two lines being on a steeper slope than the rest. The vegetation under the larch on site 2 was more dense than that under the larch on site 1,with areas of bracken, rosebay willow-herb and grass,and few areas of bare litter alone. The vegetation in the ash plantation was much denser than on any other site,consisting of grass,

CASTLE EDEN DENE , CO - DURHAM.

MAP 2

Vegetation.

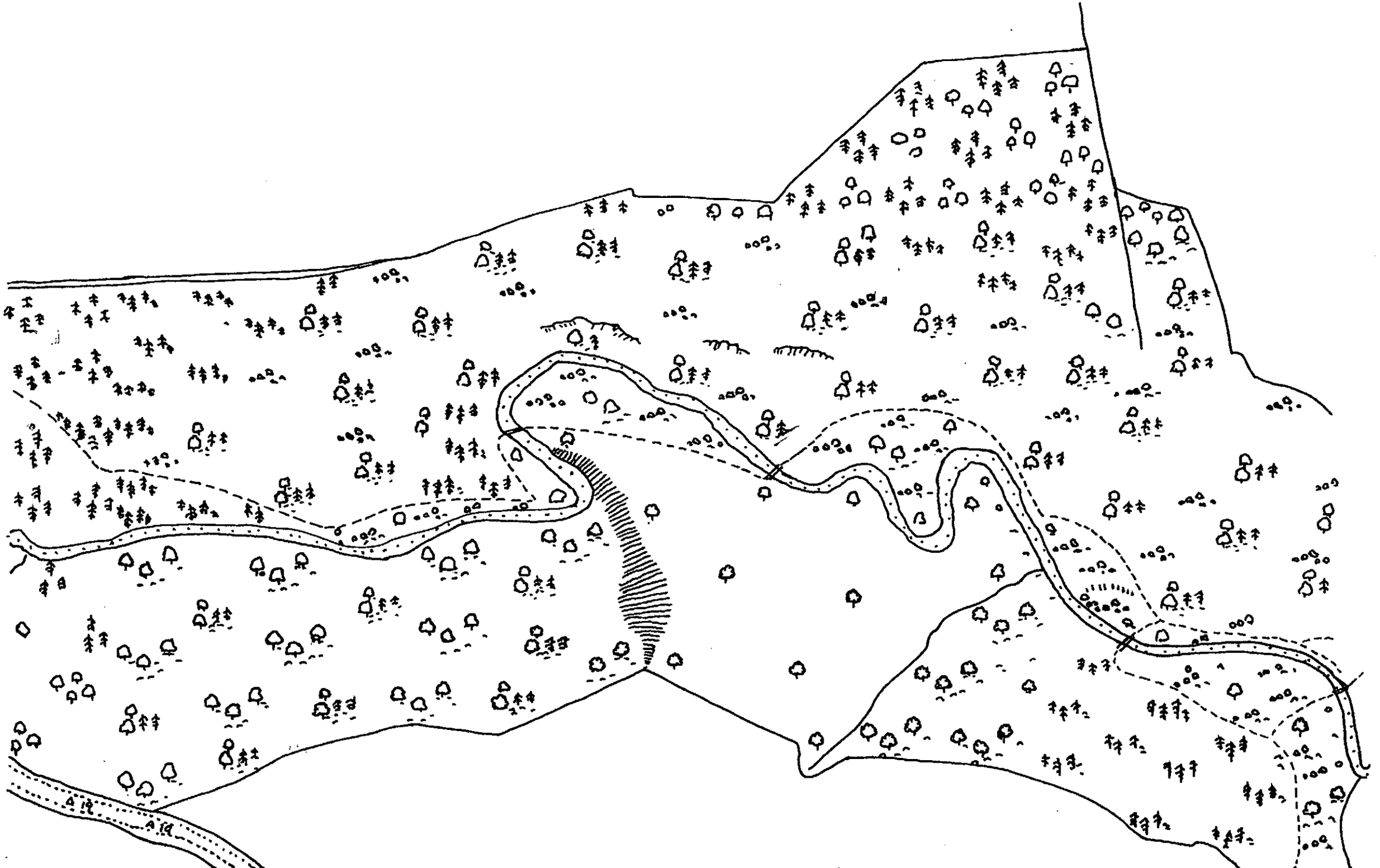
SCALE : 18·5mm = 50 metres

KEY.

 - ASH

 - LARCH

 - SYCAMORE



bramble,rosebay willow-herb,raspberry (Rubus idaeus), Tufted Hair-grass (Deschampsia caespitosa),and hogweed (Heracleum sphondylium). This site was only used once for main flea-collecting due to the relatively fewer rodents caught in all but the trap-lines in the ash plantation (R.Handley,pers.comm.)

Site 3,which lay on a steep slope on the same side of the stream as site 2,close to the roadworks,was in more open woodland,with wild garlic (Allium ursineum) as the dominant plant over much of the area. Wood anemone (Anemone nemorosa),in the spring,and bracken and ferns (Dryopteris filix-mas and Dryopteris dilatata) formed a sharp boundary at the western end. By the time the main flea-collecting was started on this site,much of the wild garlic and wood anemone had died down,leaving areas of bare soil with a very thin grass cover. The lowest grid-line,near to the stream,lay in denser vegetation of grass, bracken and rosebay willow-herb. This site was the wettest,overall,forming an unstable ground surface under conditions of heavy rain such as occurred during the last week of trapping (18th-24th July).

SECTION 3

Methods.

The rodents were trapped alive in Longworth mammal traps,provided with a small amount of hay for bedding and wheat and/or rolled oats as food. The weight,sex and sexual condition were recorded for each capture,and the rodents were toe-clipped before release after their initial capture. The trap position of each capture was noted in order to discover any correlation between flea infestation and area of capture.

The rodents had to be disinfested in the field rather than in a laboratory,in order not to disturb other work being carried out on them at the same time, over the same area. Most workers,under these conditions, remove the rodent directly from the trap. However,this does not provide any safeguard against the rodent escaping. In the present study,therefore,the rodents were removed from the traps by tipping the trap contents into a polythene bag and then extracting the rodent from the bag, leaving the bedding and fleas in situ. The majority of fleas were recovered from the bedding. Very few fleas apart from H.t.talpae were found on the hosts. In contrast, other workers have found that the bulk of the fleas were on the hosts rather than in the bedding. This difference was probably due to the procedure used for removing the animal from the trap,which may have dislodged most of the fleas. After removal of the rodent for examination, the polythene bag was sealed and marked for subsequent sorting in the laboratory. The trap was checked to ensure that no fleas were still present,and then rebedded and rebaited.

To remove any fleas still present on the rodent,air

was sucked through the fur by means of a pooter and the fur rubbed to dislodge any firmly fixed individuals. Although the number of fleas actually found on the host was very small this would not seem to be due to operational error since it was found that other means of removing the fleas,for example,by blowing the fur while holding the rodent over a white cloth (Evans,1950),did not produce any further specimens. The condition of the undergrowth and the fact that a number of the trapping sessions were carried out in heavy rain,made the use of a pooter the quicker and more satisfactory method.

A fixed grid was used throughout the trapping period on all sites. On site 1,where most of the trapping was carried out,the traps were set in the open position and left in place on the grid most of the time in between trapping sessions. It was felt that this would accustom the rodents to their presence and therefore minimise the effect of unfamiliar traps when trapping actually started. On sites 2 and 3 the traps were not left down permanently,but were laid in position a few days before trapping began and set open to accustom the rodents to their presence. It was found that many of the traps were visited during the period they were set open,any food present being eaten and large numbers of fecal pellets left. In these instances,since there was a chance that stray fleas might have been left,the bedding was changed before the traps were set. A proportion of this bedding was searched for fleas in the laboratory,but none were found to be present. Possibly under trap conditions the fleas only leave the host if the animal is stressed

by being unable to escape. Alternatively,the fleas may leave the host if the bedding in the trap is warmed, or the rodent may be more fastidious about cleaning when confined,so that the fleas escape into the bedding.

Several studies have dealt with the role of bedding in the trap and its significance in preventing loss of fleas from the animal and from the trap. Ashby,Bolton and Crawley,(unpublished),who did not put bedding in the traps,to facilitate the counting of the fleas, carried out an experiment to find the percentage loss of fleas from the rodent and trap. Clethrionomys known to be free of fleas were infested with a known number of fleas and left in a clean Longworth trap under field conditions for 24 hours. The extent of emigration was then determined by deduction of the number of fleas subsequently recovered from the number originally present. The fleas lost were assumed to have left the trap,but they may in fact have been eaten by the rodent during cleaning. Ashby,Bolton and Crawley (unpublished) found that during fair weather the mean loss of fleas,as a percentage of the original number present on the rodent, was 43%,and during rainy weather 23%,giving an overall mean loss of 31%. Unfortunately it was not possible to undertake any experiments during the present study to determine the loss of fleas from traps provided with bedding.

Site 1 was trapped for six sessions of varying length over a period of eleven weeks extending from mid May to mid July. This gave a total of twenty five days trapping. Site 3 was trapped for a period of seven

consecutive days in July,corresponding with the last trapping session on site 1,to gain data on rates and levels of infestation. Site 2 was trapped for two non-successive days in July. These coincided with the first and last days of trapping on site 3. It had been hoped that this would show the effect of disinfestation on site 3,but in fact,too few rodents and fleas were caught on site 2 for any conclusions to be drawn.

In addition,various traplines were set on sites 2 and 3 at intervals to determine the flea population present,but numbers of rodents caught on these were so low that no significance can be placed on the results.

SECTION 4

The Species Composition of the Host Fauna.

The three sites studied (see map 1) carried mainly two species of small mammals - Apodemus sylvaticus, the long-tailed field mouse, and Clethrionomys glareolus, the bank vole. Their relative abundance differed greatly on the three sites, this being one factor possibly helping to give rise to the different patterns of flea infestation which were observed (see page14). The total number of captures made over the three month period were 76 Apodemus and 303 Clethrionomys divided among the three sites as follows:

Site 1 -	75 Apodemus	and	161 Clethrionomys
Site 2 -	1 Apodemus	and	27 Clethrionomys
Site 3 -	0 Apodemus	and	115 Clethrionomys

(See also Table 1)

Also caught in the Longworth traps were two common shrews (Sorex araneus) - one on site 1 and one on site 3 - and a mole (Talpa europaea) on site 1. Other trapping, by R.Handley, without flea removal, proved site 3 to be genuinely a single species area for Clethrionomys; but his trapping figures showed that the trapping values obtained on site 2 underestimated the proportion of Apodemus present in this trapping area. The reasons for this are not obvious, but the short period (2 days) used for trapping fleas on this site might be one factor involved in the low Apodemus catch. Microtus was known to be present in the open grassland close by the east end of site 3 but none were caught on the grid used for flea-collecting; neither were any Apodemus caught on this grid though a few were caught by R.Handley during trapping on a grid immediately to the east of site 3 and continuous with it.

SITE 1	APODEMUS	CLETHRIONOMYS	SOREX	TALPA
No.of individual animals caught	17	45	1	1
Total no.of animals caught	75	161	1	1
SITE 2				
No.of individual animals caught	1	22	-	-
Total no.of animals caught	1	27	-	-
SITE 3				
No.of individual animals caught	-	35	1	-
Total no.of animals caught	-	115	1	-
TOTAL AREA				
No.of individual animals caught	18	102	2	1
Total no.of animals caught	76	303	2	1

Table 1 - The Distribution of Host Species with respect to Area.

Apodemus was found to be associated with conditions of sparse ground cover,which would explain its distribution on site 1 and its absence from site 3. It might also explain its low occurrence on site 2 during the trapping in late July,since by this time there was a fairly dense ground cover under the larch woodland.

Clethrionomys was found to be associated with conditions of more dense undergrowth such as occurred on site 3 and parts of site 1.

The shrews and mole were unable to survive in the traps,being carnivorous and needing frequent food supplies. The survival of voles and mice was nearly 100% until July when the death rate rose,abruptly. This was perhaps due to the colder,wetter conditions after two months of predominantly warm,dry weather.

It was suggested (Ashby,pers.comm.) that the increased mortality of voles might be due to the practice of visiting the traps only once daily. It seems likely that under favourable conditions,rodents can survive for up to 24 hours in a Longworth trap,provided that bedding and food are sufficient. However,under less favourable conditions,much shorter periods of captivity may prove fatal. It was expected that the influx of juveniles into the population in July would lead to increased trap mortality due to the fact that juveniles have less ability to survive in adverse conditions. In fact only two of the dead animals were juveniles,the majority being fecund males. (See Table 2) All the dead animals were Clethrionomys;there were no deaths of Apodemus in the traps.

SITE	No.of captures	No.of dead animals
1	83	5 fecund males
2	28	2 fecund males;1 lactating female
3	115	3 fecund males;2 juveniles

Table 2 - The site distribution of dead voles in traps in July.

SECTION 5

The Species Composition of the Flea Fauna.

During the trapping period a total of 528 fleas were collected, belonging to 8 species. (See Table 3a).

In a study of small mammal fleas, Evans and Freeman (1950) found C.n.vulgaris to be the most abundant species on both Apodemus and Clethrionomys, forming approximately 80% of the total flea collection from each host species. In the present study the proportion of C.n.vulgaris was found to be lower, forming about 65% of the total flea collection on Apodemus and 42% on Clethrionomys. On site 3 C.n.vulgaris was not the commonest species, Mal.p.mustelae being more abundant in this case. This may be due to the fact that the only host species caught on site 3 was Clethrionomys, and Mal.p.mustelae was generally found to be more abundant on Clethrionomys than on Apodemus. (See Table 3b).

SITE	Total no. rodents caught	C.n. vulgaris		Mal.p. mustelae		Mega. turbidus		Other species			
		No. caught	% in total flea collection	No. caught	% in total flea collection	No. caught	% in total flea collection	No. caught	% in total flea collection	Total no. fleas collected	Mean no. fleas / rodent
1	39	17	39	3	7	23	52	1	2	44	1 1
2	28	8	32	4	16	12	48	1	4	25	0 9
3	115	68	37	90	49	20	11	7	4	185	1 6

Table 4 - A comparison of the species composition of the total flea collection from each site for the trapping session 18 - 24th July

A comparison of the species composition of the flea fauna from sites 1,2 and 3 for the trapping period 18th-24th July, given in numerical form in Table 4 above and as

HOST	C.n.vulgaris	Mal.p.mustelae	Mega.turbidus	H.t.talpae	P.s.soricis	P.s.spectabilis	R.pentacantha	D.d.dasycnema	TOTAL
Clethrionomys	176	140	87	6		8	2		419
Apodemus	70	7	26	3			1		107
Sorex					1			1	2

Table 3a - The distribution of flea species on the animals present (all sites).

HOST	% C.n.vulgaris	%Mal.p.mustelae	%Mega.turbidus	% H.t.talpae	%P.s.spectabilis	%R.pentacantha	TOTAL
Clethrionomys	42	34	21	1	2	1	419
Apodemus	65	6	24	3		1	107

Table 3b - The distribution of flea species on the animals present as a %age of the total catch/host

SITE	C.n.vulgaris	Malp.mustelae	Mega.turbidus	H.t.talpae	Pal.s.soricis	P.s.spectabilis	R.pentacantha	D.d.dasycnema	TOTAL
1	166	52	80	6	1	2	3		310
2	10	4	13	1					28
3	70	91	20	2		6		1	190

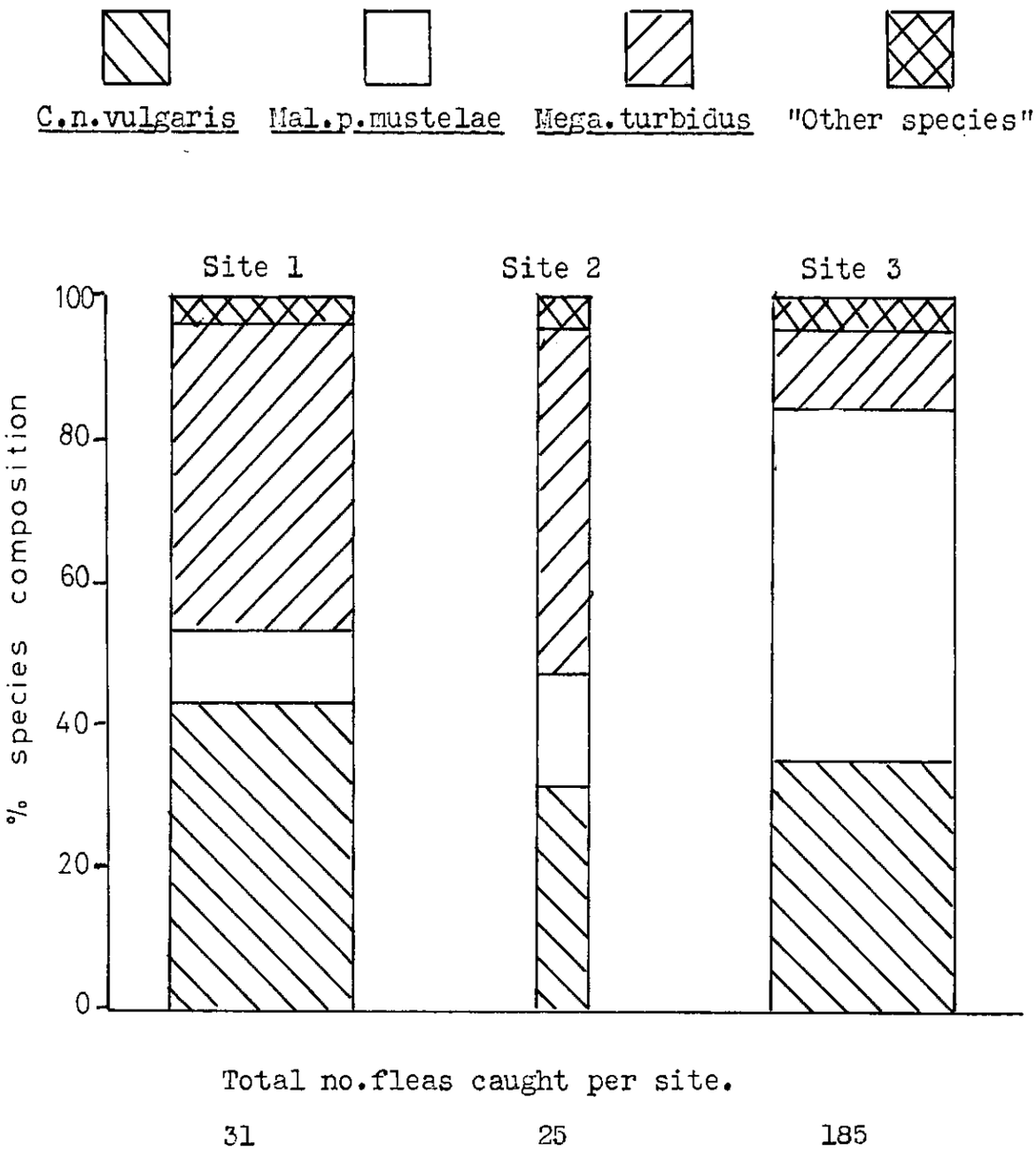
Table 3c - The distribution of flea species on the sites studied (all amimals)

SITE	% C.n.vulgaris	% Mal.p.mustelae	%Mega.turbidus	% H.t.talpae	%P.s.spectabilis	%R.pentacantha	%Dddasycnema	TOTAL
1	54	17	26	2	1	1		310
2	36	1	46	4				28
3	37	48	13	1	3		1	190

Table 3d - The distribution of flea species on the sites studied as a %age of the total catch on each site.

a percentage in Graph 1 ,shows that sites 1 and 2 had a similar percentage species composition. Site 3 had a similar percentage of C.n.vulgaris to the other two sites but a much higher percentage of Mal.p.mustelae. Very few Mega.turbidus were caught on site 3.

GRAPH 1 - The percentage species composition of the total flea collection on Clethrionomys from sites 1,2 and 3 for the trapping session 18 - 24 July.



NB. The width of the column is proportional to the length of the trapping period.

SECTION 6

Seasonal Changes in the Species Composition of the Flea Population.

During the trapping period on site 1 a change in the prevalence of flea species was found both in respect of average numbers caught on the rodents and in percentage species composition of the catch.

From Table 5 it can be seen that there is a gradual decrease in the percentage of C.n.vulgaris and Mal.p.mustelae in the flea population collected with an associated increase in the percentage of Mega.turbidus. The percentage of "other species" - H.t.talpae, R.pentacantha and P.s.spectabilis - remained approximately constant during the three months.

Table 6 shows the monthly species composition of the flea catch on Apodemus and Clethrionomys separately. The percentage flea species composition showed a similar monthly trend on each host in the case of the flea species C.n.vulgaris and Mega.turbidus. On Apodemus, no Mal.p.mustelae were caught after the first month of trapping.

Graph 2 shows the percentage species composition of the total flea collection at each trapping session. It shows a similar trend in the change in species composition to that shown by the monthly table. It also shows a very rapid increase in the percentage composition of Mega.turbidus between the first and second trapping sessions. (This may have been a result of staggered seasonal emergence of the fleas, the emergence of Mega.turbidus being associated with higher temperatures than that of Mal.p.mustelae and C.n.vulgaris.)

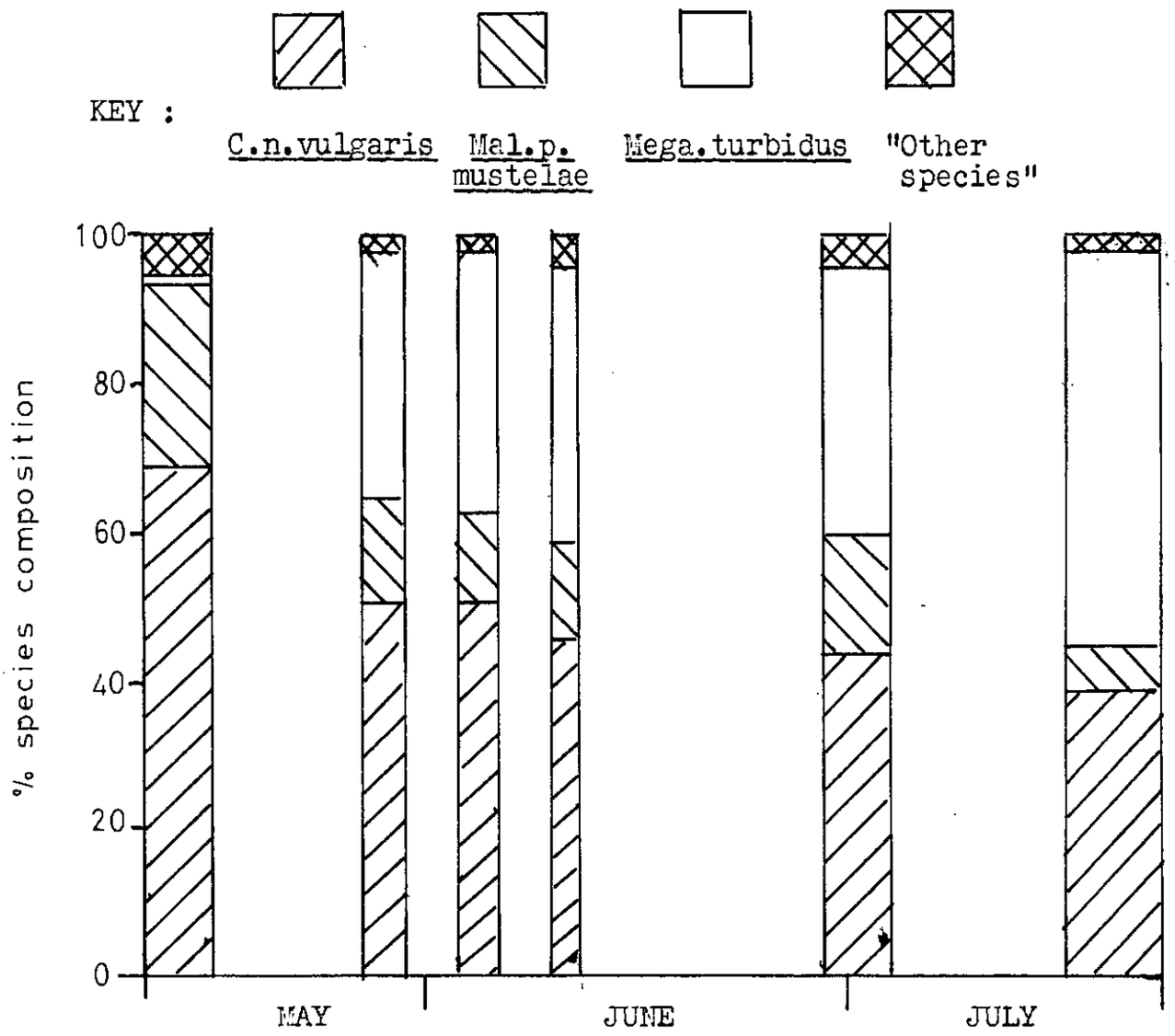
TRAPPING SESSION	DATE	Total no. rodents caught	No. of C.n.vulgaris caught	%C.n.vulgaris in total / session	No. of M.p.mustelae caught	%M.p.mustelae in total / session	No. of Mega. turbidus caught	%Mega. turbidus in total / session	No. of "other species" caught	%"other species" in total / session	Total no. fleas collected
1 (11-15 MAY)	11-5-70	8	19		2		0		0		21
	12-5-70	8	14		9		0		1		24
	13-5-70	11	18	68%	5	26%	0	1%	1	5%	24
	14-5-70	12	12		9		0		3		24
	15-5-70	10	7		2		1		0		10
2 (27-29 MAY)	27-5-70	2	0		0		0		0		0
	28-5-70	6	5	51%	1	14%	10	33%	1	2%	17
	29-5-70	15	17		5		4		0		26
3 (3-5 JUNE)	3-6-70	11	12		2		4		0		18
	4-6-70	9	6	51%	1	11%	3	36%	1	2%	11
	5-6-70	14	9		3		12		0		24
4 (10&11 JUNE)	10-6-70	18	5		0		7		1		13
	11-6-70	12	5	45%	3	14%	1	36%	0	5%	9
5 (30 JUNE-4 JULY)	30-6-70	7	6		1		2		0		9
	1-7-70	7	2		0		0		0		2
	2-7-70	14	7	44%	1	16%	12	36%	0	4%	20
	3-7-70	16	2		5		1		1		9
	4-7-70	18	3		0		1		1		5
6 (18-24 JULY)	18-7-70	2	1		0		4		0		5
	19-7-70	4	1		1		3		0		5
	20-7-70	5	3		0		4		0		7
	21-7-70	4	2	39%	0	7%	2	52%	0	2%	4
	22-7-70	6	2		0		5		0		7
	23-7-70	4	0		0		3		1		4
	24-7-70	14	8		2		2		0		12

Table 5 - Total numbers of flea species caught per trapping-day on site 1.

HOST SPECIES	DATE	Number of trapping days	Total no. rodents caught	Total no. fleas caught	C.n. vulgaris: No. caught	C.n. vulgaris: Av. no. caught / trapping day	C.n. vulgaris: % in total flea collection	Mal.p. mustelae: No. caught	Mal.p. mustelae: Av. no. caught / trapping day	Mal.p. mustelae: % in total flea collection	Mega. turbidus: No. caught	Mega. turbidus: Av. no. caught / trapping day	Mega. turbidus: % in total flea collection	Other species: No. caught	Other species: Av. no. caught / trapping day	Other species: % in total flea collection
BOTH SPECIES	MAY	8	72	146	92	11.5	62	33	4.1	23	15	1.9	10	6	0.8	4
	JUNE	6	71	83	43	7.2	52	9	1.5	11	29	4.8	35	2	0.3	2
	JULY	11	93	89	31	2.8	38	9	0.8	11	38	3.5	47	3	0.3	4
	Total May - July	25	236	310	166	6.6	54	51	2.0	16	82	3.3	26	11	0.4	4
					C.n. vulgaris			Mal.p. mustelae			Mega. turbidus			Other species		
	DATE	Number of trapping days	Total no. rodents caught	Total no. fleas caught	No. caught	Av. no. caught / rodent	% in total flea collection	No. caught	Av. no. caught / rodent	% in total flea collection	No. caught	Av. no. caught / rodent	% in total flea collection	No. caught	Av. no. caught / rodent	% in total flea collection
APODEMUS	MAY	8	37	70	48	1.3	68	7	0.2	10	10	0.3	14	5	0.1	7
	JUNE	6	22	20	14	0.6	70	0	-	-	6	0.3	30	0	-	-
	JULY	11	16	18	8	0.5	44	0	-	-	10	0.6	56	0	-	-
	Total May - July	25	75	108	70	0.9	65	7	0.1	6	26	0.3	24	5	0.1	5
CLETHRIONOMYS	MAY	8	35	76	44	1.3	58	26	0.7	34	5	0.1	7	1	-	1
	JUNE	6	49	63	29	0.6	46	9	0.2	14	23	0.5	36	2	-	3
	JULY	11	77	58	23	0.3	36	9	0.1	14	28	0.4	44	3	-	5
	Total May - July	25	161	197	96	0.6	49	44	0.3	22	56	0.3	28	6	-	3

Table 6 - Monthly species composition of rodent flea collection.

GRAPH 2 - The percentage species composition of the total flea collection from each trapping session (Site 1)



Total no.fleas caught per session.

103 43 53 22 45 44

NB. The width of the column is proportional to the length of the trapping session.

SECTION 7

The Sex Ratio in Fleas.

Many workers,such as Mitzmain (1910),Evans and Freeman (1950) and Cotton (1965),have demonstrated that, at least on the bodies of the hosts,there is a marked inequality in the numbers of male and female fleas present,females being the more abundant sex. This may be due to differences in behaviour between the flea sexes, the females needing to feed before egg-laying. For example,Buxton (1938) found that significantly more female than male fleas appeared on the host after equal numbers of the two sexes of flea were placed in a nest-box occupied by a mouse. There may be a difference in emergence rates of the two sexes of flea in the nest (Hirst,1924). There is also a known difference in life-expectancy,male fleas usually dying soon after copulation (Mitzmain,1910).

The differences in sex ratio of the fleas found on the host are shown in Table 7 for the present study. Only in the case of the three main flea species C.n.vulgaris,Mal.p.mustelae and Mega.turbidus were the numbers of fleas caught sufficient for the calculation of the sex ratio. On Apodemus the numbers of Mal.p.mustelae caught were very low,and therefore the apparently reduced percentage of males present differs significantly from a 1:1 ratio only at the 10% level ($p =< 0{\cdot}1$). For the three main flea species on both hosts (considered jointly) the proportion of females to males was significantly greater than 1:1 ($p =< 0{\cdot}01$ for Apodemus and $p =< 0{\cdot}001$ for Clethrionomys). The two host species appeared to differ significantly in the percentage of males of Mega.turbidus present in their

	Flea Species	No. ♂ Fleas	No. ♀ Fleas	% ♂ Fleas	Sex Ratio ♂ : ♀	P ✱
APODEMUS	C.n.vulgaris	27	43	39	1:1·6	> 0·05
	Mal.p.mustelae	1	6	-	-	> 0·05
	Mega.turbidus	11	14	44	1:1·3	< 0·9
	H.t.talpae	0	3	-	-	-
	R.pentacantha	0	2	-	-	-
	P.s.spectabilis	-	-	-	-	-
	Total flea collection from APODEMUS	39	68	36	1:1·7	< 0·01
CLETHRIONOMYS	C.n.vulgaris	37	59	39	1:1·6	< 0·05
	Mal.p.mustelae	17	27	39	1:1·6	< 0·2
	Mega.turbidus	10	47	21	1:4·7	< 0·001
	H.t.talpae	1	2	-	-	-
	R.pentacantha	0	1	-	-	-
	P.s.spectabilis	1	1	-	-	-
	Total flea collection from CLETHRIONOMYS	66	137	32	1:2·1	< 0·001
TOTAL ANIMAL COLLECTION	C.n.vulgaris	64	102	39	1:1·6	< 0·01
	Mal.p.mustelae	18	33	35	1:1·8	< 0·05
	Mega.turbidus	21	61	26	1:2·9	< 0·001
	H.t.talpae	1	5	-	-	-
	R.pentacantha	0	3	-	-	-
	P.s.spectabilis	1	1	-	-	-
	Total flea collection from all animals	105	205	34	1:2	< 0·001

Table 7 - Species Distribution and Sex Ratio of Fleas Collected

✱ Probability that the sex ratio differs from 1:1 only by chance.

flea populations ($p =< 0.05$), whereas in the case of C.n.vulgaris, which was the most abundant species of flea collected, there was no evidence of such a difference ($p =< 0.9$). The sex ratio of the total collection of all species of flea on each host, 1:1·74 for Apodemus and 1:2·08 for Clethrionomys, was not significantly different ($p =< 0.8$).

It is impossible to decide from the results obtained whether there is any difference in sex ratio between the three rarer species of flea collected - H.t.talpae, R.pentacantha and P.s.spectabilis - since the numbers caught were so small. However, if the values for the three species from both hosts are considered together, then the sex ratio obtained of 2:9 in favour of females gives some indication that an unequal sex ratio does exist in all the flea species collected.

SECTION 8

Flea Distribution with respect to Host Factors.

a. Distribution with respect to sex of host.

The present study confirms previous reports that males of both Apodemus and Clethrionomys are more highly infested with fleas than the females. This unequal intensity of infestation may be related to the breeding habits of the female rodent. Ashby and Crawley (1967) found a mean infestation level of fleas on male rodents of 4·47± 0·34 and on female rodents of 1·78 ± 0·29. The mean infestation levels found in the present work were markedly lower in both sexes of rodent but were still markedly higher in males than in females,the mean values being 1·62 for males and 0·80 for females (see Table 9).

In the study by Ashby and Crawley (1967) only two flea species,C.n.vulgaris and Mal.p.mustelae were found to be abundant. In the present study Mega.turbidus was also present,in varying degrees of abundance,on the three sites studied. From Table 8 it can be seen that Mega.turbidus is the second most abundant flea species on all but the male Clethrionomys. The higher proportion of Mal.p.mustelae on male Clethrionomys may be due to the fact that the latter hosts formed a higher proportion of the catch during the first trapping period (11th - 15th May),when most of the Mal.p.mustelae were obtained (see page16). If the populations of fleas in the rodent nests in the Dene could be shown to exhibit a similar rise in the incidence of Mega.turbidus to that found in the flea collections from the bodies of the rodent hosts,then the longer periods of time spent by the female Clethrionomys in the nest during the breeding season would explain the unequal distribution of Mega.turbidus between the sexes of Clethrionomys (see Table 11).

FLEA SPECIES	APODEMUS				CLETHRIONOMYS			
	♂		♀		♂		♀	
	No. of fleas	Mean no. fleas	No. of fleas	Mean no. fleas	No. of fleas	Mean no. fleas	No. of fleas	Mean no. fleas
C.n.vulgaris	38	1·19	26	0·62	83	0·88	13	0·21
Mal.p.mustelae	4	0·12	3	0·07	38	0·40	7	0·11
Mega.turbidus	13	0·41	13	0·31	27	0·29	26	0·42
Mal.p.mustelae + Mega.turbidus	17	0·53	16	0·38	65	0·69	33	0·53

Table 8 - Species Distribution of Fleas on ♂ and ♀ Apodemus and Clethrionomys.

DATE	MALE APODEMUS			FEMALE APODEMUS		
	No. of captures	No. of fleas	Mean no. fleas/capture	No. of captures	No. of fleas	Mean no. fleas/capture
MAY	12	29	2·42	20	25	1·25
JUNE	9	9	1·00	12	11	0·92
JULY	7	11	1·57	10	7	0·70
DATE	MALE CLETHRIONOMYS			FEMALE CLETHRIONOMYS		
	No. of captures	No. of fleas	Mean no. fleas/capture	No. of captures	No. of fleas	Mean no. fleas/capture
MAY	26	61	2·35	9	10	1·11
JUNE	32	42	1·31	11	13	1·18
JULY	37	44	1·19	42	25	0·59

Table 9 - The monthly distribution of fleas on ♂ and ♀ Apodemus and Clethrionomys.

DATE	APODEMUS						CLETHRIONOMYS					
	♂			♀			♂			♀		
	No. of captures	No. of fleas	Mean no. fleas / capture	No. of captures	No. of fleas	Mean no. fleas / capture	No. of captures	No. of fleas	Mean no. fleas / capture	No. of captures	No. of fleas	Mean no. fleas / capture
11 - 15 MAY	8	15	1·9	12	11	0·9	20	51	2·5	4	5	1·2
27 - 29 MAY	4	14	3·5	8	14	1·7	6	10	1·7	5	5	1·0
3 - 5 JUNE	5	7	1·4	7	10	1·4	16	23	1·4	10	13	1·3
10 - 11 JUNE	4	2	0·5	5	1	0·2	16	19	1·2	5	0	0
30 JUNE- 4 JULY	4	3	0·7	5	2	0·4	23	29	1·3	26	9	0·3
18 - 24 JULY	3	8	2·7	5	5	1·0	14	15	1·1	16	16	1·0
TOTAL	28	49	1·7	42	43	1·0	95	147	1·5	66	48	0·7

Table 10 - Mean number of fleas per trapping session on ♂ and ♀ Apodemus and Clethrionomys on site 1.

b. Distribution with respect to sexual condition of host.

Ashby,Bolton and Crawley (unpublished),using four categories of sexual condition in female rodents,found perforate and lactating females to be less heavily infested than those which were pregnant or imperforate. O'Brien and Tilbrook (unpublished),using only the two categories pregnant and non-pregnant,found that the pregnant female rodents had a significantly higher infestation level than the non-pregnant females,juveniles being excluded from the results. This higher infestation level may have been due to the inclusion of lactating females,which were less heavily infested,in the same category as perforate and imperforate females.

In the present study the female rodents were divided into four categories on the basis of their sexual condition at the time of capture:perforate,pregnant, lactating and other. This last category included imperforate females and those whose sexual condition could not be definitely identified. The imperforate females were not placed in a separate category since their numbers were too low to be statistically significant.

From the last section of Table 11 (both species,all sites) it can be seen that lactating females in the sample obtained have a lower percentage of rodents infested and a lower numbers of fleas per rodent,than the remaining categories. The low proportion of lactating females infested is at least suggestive,though significant only at the 20% level. When calculating the mean infestation, if only infested female rodents are considered,then there

Host species	Site	Sexual condition of host	No. of ♀ rodents	No. of ♀ rodents infested	% ♀ rodents infested	No. of fleas	Mean no. fleas / rodent	Mean no. fleas / infested rodent
CLETHRIONOMYS	SITE 1	Perforate	21	11	52	22	1·0	2·0
		Pregnant	21	5	-	13	0·6	2·6
		Lactating	10	3	-	4	0·4	1·3
		Other	10	5	-	8	0·8	1·6
	SITE 2	Perforate	2	1	-	4	2·0	4·0
		Pregnant	9	5	-	6	0·7	1·2
		Lactating	3	0	-	0	0	0
		Other	1	0	-	0	0	0
	SITE 3	Perforate	12	5	42	15	1·2	3·0
		Pregnant	20	11	55	32	1·6	2·9
		Lactating	1	0	-	0	0	0
		Other	10	5	-	9	0·9	1·8
	ALL SITES	Perforate	35	17	49	41	1·1	2·4
		Pregnant	50	21	42	51	1·0	2·4
		Lactating	14	3	21	4	0·3	1·3
		Other	21	10	48	17	0·8	1·7
APODEMUS	SITE 1	Perforate	4	1	-	6	1·5	6·0
		Pregnant	20	9	45	16	0·8	1·8
		Lactating	12	3	25	13	1·1	4·3
		Other	6	3	-	8	1·3	2·7
BOTH SPECIES	ALL SITES	Perforate	39	18	46	47	1·2	2·6
		Pregnant	70	30	43	67	1·0	2·2
		Lactating	26	6	23	17	0·7	2·8
		Other	27	13	48	25	1·0	1·9

Table 11 - Flea infestation related to the sexual condition of the female rodent host.

is no significant difference in percentage infestation with sexual condition ($p =< 0{\cdot}8$). There was no significance in percentage infestation between perforate and pregnant female rodents ($p =< 0{\cdot}9$) or between pregnant females and imperforate or indeterminate females ($p =< 0{\cdot}8$).

c. Distribution with respect to the weight of the host.

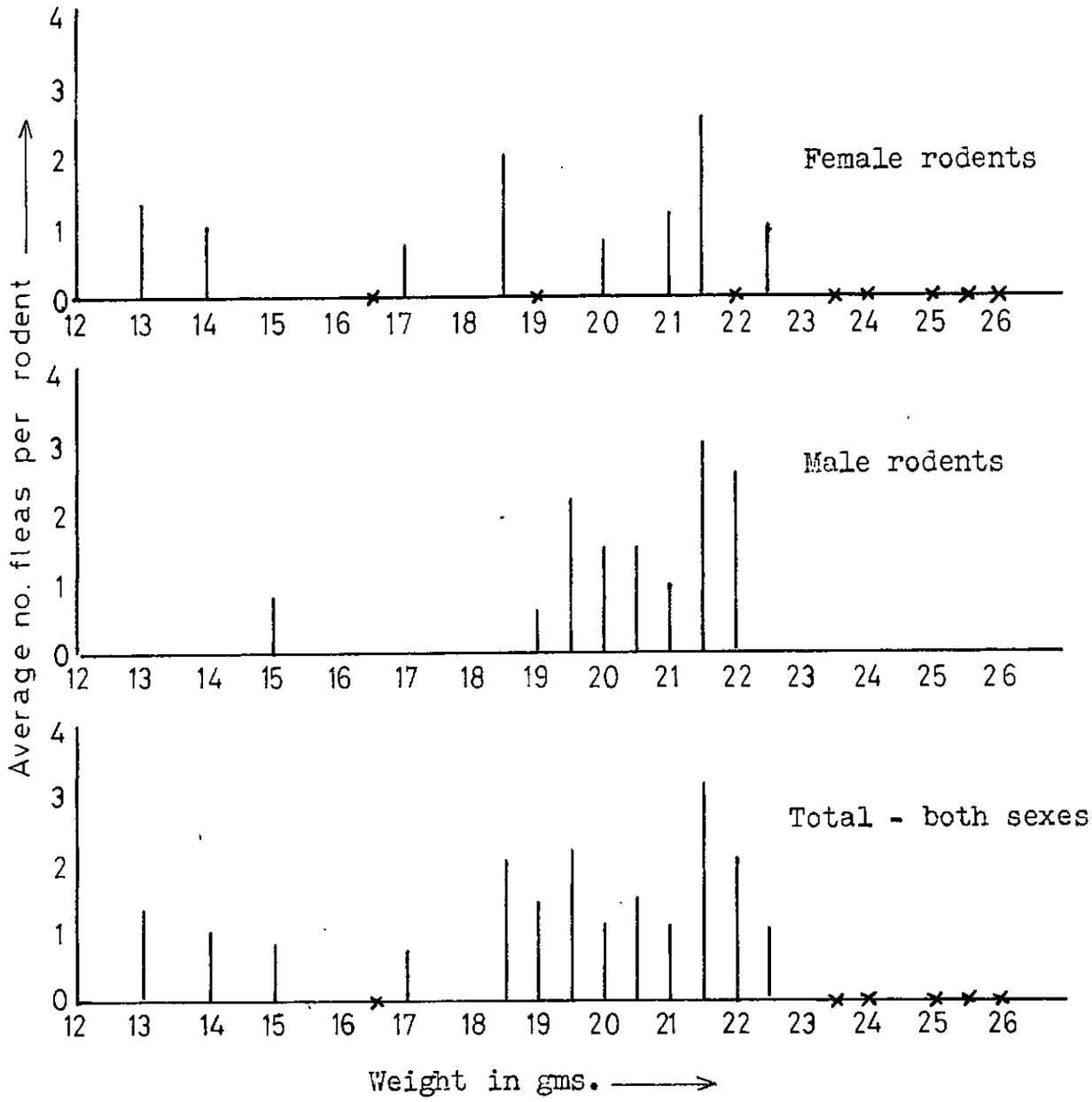
Numerous workers have attempted to discover a correlation between the weight of host and the degree of infestation. A survey in Upper Egypt (Petrie and Todd,1923) found that the infestation of fleas on rats increased with the size of the rat up to a certain weight of host and then decreased. It was suggested that this weight might signify the onset of maturity,after which the animal became more efficient at cleaning itself.

Ashby,Bolton and Crawley (unpublished),working in Castle Eden Dene,found a slight increase in flea infestation with weight of the rodent. O'Brien and Tilbrook (unpublished) also found a slight,but not statistically significant, increase in infestation with increase in weight of the rodent.

In the present study,when considering the distribution of fleas with the average weight of the animal (see Graph 3), it can be seen that there is an apparent increase in infestation with weight for both male and female Clethrionomys. The anomalous figure at 21·5 gms. for male Clethrionomys,may be partly due to a single high result. If the data is grouped into the weight classes 9 - 14·5 gms, 15 - 20·5 gms and 21 - 26·5 gms (see Table 12),the difference between the mean infestation of the total rodent catch for each of these classes is not statistically significant.

Considering the results for Apodemus separately, there is a slight increase in infestation with weight for males and a slight decrease in infestation with weight for females. However,the samples are too small for the results to be statistically significant.

GRAPH 3 - The average number of fleas per rodent with respect to weight.



Average weight of rodent in gms.	APODEMUS						CLETHRIONOMYS						TOTAL		
	♂			♀			♂			♀					
	No.of rodents	No.of fleas	Mean no.fleas / rodent	No.of rodents	No.of fleas	Mean no.fleas / rodent	No.of rodents	No.of fleas	Mean no.fleas / rodent	No.of rodents	No.of fleas	Mean no.fleas / rodent	No.of rodents	No.of fleas	Mean no.fleas / rodent
9·0 to 14·5	1	1	1·0							4	5	1·2	5	6	1·2
15·0 to 20·5	5	4	0·8	5	10	2·0	55	82	1·5	24	19	0·8	89	115	1·3
21·0 to 26·5	31	59	1·9	37	33	0·9	36	65	1·8	31	30	1·0	135	187	1·4

Table 12 - The distribution of fleas with respect to weight of rodent host.

Average weight of rodent in gms.	APODEMUS ♂			APODEMUS ♀			CLETHRIONOMYS ♂			CLETHRIONOMYS ♀			ALL ANIMALS		
	No.of rodents	No.of fleas	Mean no.fleas / rodent	No.of rodents	No.of fleas	Mean no.fleas / rodent	No.of rodents	No.of fleas	Mean no.fleas / rodent	No.of rodents	No.of fleas	Mean no.fleas / rodent	Total no. rodents	Total no. fleas	Mean no.fleas / rodent
9·5	1	1	1·0										1	1	1·0
11·0															
11·5															
12·0															
12·5															
13·0										3	4	1·3	3	4	1·3
13·5															
14·0										1	1	1·0	1	1	1·0
14·5															
15·0							4	3	0·8				4	3	0·8
15·5															
16·0															
16·5										1	0	0	1	0	0
17·0										3	2	0·7	3	2	0·7
17·5				3	4	1·3							3	4	1·3
18·0															
18·5										2	4	2·0	2	4	2·0
19·0	[illegible]			2	6	3·0	10	6	0·6	2	0	0	14	12	0·9
19·5	5	4	0·8				19	40	2·1				24	44	1·8
20·0							11	17	1·5	16	13	0·8	27	30	1·1
20·5							11	16	1·5				11	16	1·5
21·0	6	8	1·3	13	8	0·6	20	20	1·0	14	17	1·2	53	53	1·0
21·5							8	24	3·0	2	5	2·5	10	29	2·9
22·0	5	13	2·6	10	16	1·6	8	21	2·6	2	0	0	25	50	2·0
22·5										8	8	1·0	8	8	1·0
23·0	6	13	2·2										6	13	2·2
23·5	7	10	1·4	4	4	1·0				1	0	0	12	14	1·2
24·0	7	15	2·1	7	4	0·6				1	0	0	15	19	1·3
24·5															
25·0										1	0	0	1	0	0
25·5				3	1	0·3				1	0	0	4	1	0·2
26·0										1	0	0	1	0	0

Table 13 - The distribution of fleas with respect to the average weight of the host.

SECTION 9

Reinfestation.

There have been several studies of the problem of the rate of reinfestation of rodent hosts by the various species of flea. Meyer (1938) found that rodents with their fleas removed regained many fleas within a very short time. Evans and Freeman (1950) found that there was no significant difference between the numbers of fleas on hosts recaptured after 24 hours and the numbers present on the hosts after an interval of 30 days between captures. Janion (1960) showed infestation to be independant of disinfestation among rodents trapped at 9 hour intervals. Cotton (1965) found no apparent decrease in flea abundance with the removal of fleas from rodents at daily intervals over a 4-day trapping period, and no marked decline in the numbers of C.n.vulgaris on voles trapped on successive occasions. However, O'Brien and Tilbrook (unpublished) appear to have observed a drop in the mean infestation of captures 24 hours after disinfestation, but not after intervals of 2 days or longer, when the mean infestation returned to roughly the original value.

During the first week of trapping in the present study, an attempt was made to measure the rates of reinfestation at periods shorter than 24 hours. However, insufficient results were obtained for any conclusions to be drawn. The numbers of rodents caught proved to be moderately low, even when the traps were left open for 24 hours, and insufficient traps were available for two to be placed at each grid position.

When considering the results in the light of the previous work in the Dene, the first point to be made is that the present infestation values are considerably

Table 14 - Rate of flea reinfestation of rodents trapped at 24 hour intervals.

All sites	Site 3	ALL SITES			SITE 3			SITE
Av. no. fleas / individual		% individs. infested	No. of individuals infested	No. of individuals	% individuals infested	No. of individuals infested	No. of individs.	
16	18	60%	58	97	63%	22	35	Rodents caught first time and disinfested (1)
18	10	66%	19	29	56%	9	16	Rodents caught 24 hrs. after (1) and disinfested (2)
14	16	67%	8	12	70%	7	10	Rodents caught 24 hrs. after (2) and disinfested (3)
16	16	60%	6	10	50%	4	8	Rodents caught 24 hrs. after (3) and disinfested (4)
15	15	83%	5	6	83%	5	6	Rodents caught 24 hrs. after (4) and disinfested (5)
17	17	67%	2	3	67%	2	3	Rodents caught 24 hrs. after (5) and disinfested (6)
20	20	50%	1	2	50%	1	2	Rodents caught 24 hrs. after (6) and disinfested (7)

lower than those found by Ashby,Bolton and Crawley (unpublished) and O'Brien and Tilbrook (unpublished). One of the reasons for this lowered infestation level may be that there has been a sudden recent increase in the vole population of the area,without an associated increase in the flea population on the rodent.

It can be seen from Table 14 that the results from the present study support the views of Cotton (1965) that there is little change in either the percentage number of animals infested or the average infestation rate with subsequent recapture and disinfestation at 24 hour intervals after capture. Neither the mean infestation rate per animal for the total area,nor that for site 3 considered alone,shows a decline with time,a result contrary to that found by O'Brien and Tilbrook (unpublished).

Table 15 shows the reinfestation levels for different intervals of time between recaptures. Since for the longer intervals of time the numbers of rodents caught were small,the data has been grouped for the time intervals 3 - 8 days,9 - 20 days and 21+ days.

As can be seen from Table 16 ,there is no significant difference between either the percentage of the rodent catch infested or the mean infestation rate for captures and recaptures made during this study. This does not contradict the findings of Janion (1960) that infestation is independant of disinfestation,but the present samples are possibly too low to show any trend.

Table 15 - The Level of Flea Reinfestation of Rodents Trapped at Varying Intervals of Time after Previous Capture and Disinfestation (Site 1).

Host species		Time interval	MALE RODENTS			FEMALE RODENTS			TOTAL MALE + FEMALE RODENTS		
			No. of individual rodents	No. infested	Mean no. fleas / rodent	No. of individual rodents	No. infested	Mean no. fleas / rodent	No. of individual rodents	No. infested	Mean no. fleas / rodent
APODEMUS	Recapture after	1st capture	8	7	1·9	8	3	1·4	16	10	1·6
		24 hrs.	9	7	2·3	10	3	1·1	19	10	1·7
		2 days	3	2	2·0	6	3	1·3	9	5	1·6
		3–8 days	6	3	1·3	8	3	0·8	14	6	1·0
		9–20 days	2	1	1·0	9	4	0·8	11	5	0·8
		21+days	4	3	1·8	1	0	0	5	3	1·4
CLETHRIONOMYS	Recapture after	1st capture	26	18	1·8	18	7	0·9	44	25	1·5
		24 hrs.	21	16	2·0	15	5	1·2	36	21	1·7
		2 days	8	7	2·2	9	2	0·4	17	9	1·3
		3–8 days	12	5	0·8	7	4	0·7	19	9	0·7
		9–20 days	11	8	1·5	11	6	0·7	22	14	1·1
		21+ days	12	6	1·2	2	0	0	14	6	1·0
BOTH SPECIES	Recapture after	1st capture	34	22	1·9	26	10	1·0	60	35	1·5
		24 hrs.	30	23	2·1	25	8	1·2	55	31	1·7
		2 days	11	9	2·2	15	5	0·8	26	14	1·4
		3–8 days	18	8	0·9	15	7	0·7	33	15	0·8
		9–20 days	13	9	1·4	20	10	0·8	33	19	1·0
		21+ days	16	9	1·3	3	0	0	19	9	1·1

Host species	Date	CAPTURES			RECAPTURES		
		No.of captures	No. infested	Total no. fleas on captures	No. of recaptures	No. infested	Total no. fleas on recaptures
APODEMUS	MAY	14	10	31	23	12	39
	JUNE	1	0	0	21	10	20
	JULY	2	1	1	14	7	16
CLETHRIONOMYS	MAY	16	12	36	19	17	40
	JUNE	8	5	6	41	21	58
	JULY	20	10	17	57	23	45
BOTH SPECIES	MAY	30	22	67	42	29	79
	JUNE	9	5	6	62	31	78
	JULY	22	11	18	71	30	61

Table 16 - The monthly distribution of flea infestation on captures and recaptures of Clethrionomys & Apodemus.

SECTION 10

Discussion.

Since this was essentially a short-term project, the results obtained could perhaps best be considered as a basis for future work rather than as a completed study. In many cases the rodent and flea samples collected were too small to be treated statistically. Therefore any conclusions drawn can only be valid if considered in the light of previous flea studies or in relation to future,more detailed projects.

Although the results from the present study were, in most respects,in close agreement with those of the two previous studies in Castle Eden Dene (Ashby and Crawley,1967, and O'Brien and Tilbrook,unpublished), some differences were noted. In the study by Ashby and Crawley (1967) no Mega.turbidus were found,even though the study was carried out in June when the species might be expected to be present. However,none of the grids used in the present study correspond with those used in the earlier study. Therefore the absence of Mega.turbidus in that study may be a site difference similar to that found between sites 1 and 3 (see page 15). If this is the case,it is not possible to explain the absence of Mega.turbidus solely on the grounds that only Clethrionomys was present (see page 14),since the trapping by Ashby and Crawley produced Apodemus and Microtus as well as Clethrionomys.

The study by Ashby and Crawley,carried out over a period of two weeks,could not show any seasonal variation in the species collected. The present study,extending over two months,though not long enough to demonstrate a true seasonal variation,suggests that there may be seasonal changes in the flea population in the Dene

similar to those found by other workers.

This apparent seasonal variation in species composition of fleas may be due to changes in population composition in the nest of the host,to differences in emergence of the adult fleas,or possibly to differences in behaviour between the flea species. Since,in the present work, nest populations of fleas were not studied,the first two possibilities cannot be ruled out. The second of these would seem to be the most probable on the basis of work done by previous studies.

It is difficult to decide whether seasonal fluctuations in the numbers of fleas per animal represent true fluctuations in the flea population,or whether they are determined by seasonal or other changes in the population of the host. Apparent changes in flea population according to season and or climate could easily be caused by fluctuations in the numbers of the host population or by a change in its activities. Certainly,true seasonal variations in flea numbers have been shown,both as regards the total number of fleas and the species composition. Early work on this was carried out by the Plague Surveys. Later work was done on the seasonal prevalence of the rabbit flea,Spilopsyllus cuniculi,(Allan,1956). More recently, Cotton (unpublished) has demonstrated a staggered seasonal emergence of fleas associated with differences in the temperature necessary for emergence. C.n.vulgaris was found to emerge in spring and early summer,needing a temperature of 13-15°C for emergence (high mortality occurred at 25°C+),while P.s.spectabilis,needing a temperature in the 20°C+ range,was found to emerge from June to December.

Using data from Davis (1934) on the fleas from

nests of Microtus spp_,a definite change in seasonal species composition can be shown,but since these results were obtained over several years from a number of areas, they may not be as significant as they appear.

Stewart and Evans (1941),working on ground squirrels, (Citellus beecheyi),found a definite seasonal change in the species composition of the two most abundant flea species present. They also found a close correlation between flea populations both on the host and at the mouths of the burrows with respect to this species change. They were unable to correlate either atmospheric or burrow temperatures with flea indices except that one flea,Diamanus montanus,was predominant while the mean temperature was below 75°F and the other flea,Hoplopsyllus anomalus,was predominant while the mean temperature was above 75°F. This may be due to an effect of temperature on emergence similar to that found by Cotton (See previous page.)

The field studies by Cole (1945) showed that in the case of Xenopsylla cheopis,the rat flea,atmospheric temperature may be one of the factors involved in the variation in the relative proportions of the sexes of flea on the host (see section 7). Females were found to predominate below 70°F while over 75°F males were caught in greater number. Allan (1956),working on the infestation of wild European rabbits with the rabbit flea Spilopsyllus cuniculi,noted a marked disparity in the proportions of males and females found on the host at certain times of the year. This may possibly be a result of a temperature difference such as that found by Cole (see above).

Although one of the aims of the present work was to investigate reinfestation levels and rates in the light of previous studies,the results were not as satisfactory as had been hoped. The low sample size obtained was not sufficient for any statistically significant conclusions to be drawn. However,certain findings such as those of the rates of reinfestation at 24 hour intervals (see page 24) suggest lines which might be profitably followed in a subsequent study.

The level of the reservoir population of fleas available to the host once it has been disinfested must play a part in determining the rate of reinfestation of the rodent. The big variations in the numbers of fleas found in nests of Microtus spp by Davis (1934),if applicable to Clethrionomys and Apodemus in the area under study,would help to explain why certain individual rodents became reinfested with as many or more fleas as before within 24 hours of disinfestation. Other individuals were not infested or had very low numbers of fleas,even at first capture. The difference may be due to some factor concerned with the nest such as its structure, temperature,the presence of predators on the fleas,or to factors associated with the host such as sexual condition (see section 8b.) or the general level of grooming activity.

Unfortunately,several lines of investigation relevent to the present study had to be omitted or abandonned due to shortage of time. It had been intended to study the flea populations in the rodent nests in conjunction with those on the bodies of the hosts. However,this was not feasible in the time available. Future work might profitably be carried out on an investigation of the relationship

between the populations of fleas on the host and those in the nest,especially with respect to the percentage species composition and sex ratio of fleas available for infesting the host.

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